

# **AUTOMATED EXPLOSION EFFECTS MODELING**

**By**

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## **INTRODUCTION**

The DoD and the Services have developed explosives safety siting regulations to govern the planning and maintenance of military and DoD contractor facilities. These regulations have traditionally been extensive and involved. For the most part, we have done a good job in maintaining high standards of conformance. We are all aware that the cuts in the DoD budget have resulted in reductions of manpower and facilities, but perhaps we haven't realized that we are losing a lot of expertise in the engineering and design communities as well. Government expertise in explosives safety is extensive. The private sector also has a great deal of explosives safety expertise. The trends of significant reductions of government spending in explosives safety related RTD&E programs and blast-resistant construction is taking a toll on this expertise. As existing talent retires or moves into other areas where work opportunities are more abundant, development and training of new explosives safety experts is moving very slowly. The end result is that we may be approaching a time when the demand for government explosives safety experts could outpace the supply. The need exists for automated tools to make explosives safety experts at all levels more productive and cost effective to assist DoD installations with their safety requirements.

Automating the predictions of explosives effects is a multi-dimensional process. It must meet the needs of users that have a wide variety of requirements. No one solution will be acceptable or useful to all. Automation requirements range from precise implementation of engineering and scientific principles that require extensive knowledge and judgement to approximate predictions that can assist those with little background or expertise in explosives safety. This paper examines potential tools for use by the both the explosives safety oriented engineer/scientist, authorities and planners. Groundwork is being laid here to prepare for the planning, consolidation, and development of these tools over the next few years.

## **SPECIALTIES IN EXPLOSIVES SAFETY**

There are three major areas of specialty in the explosives safety field. One area is the explosives safety engineer/scientist, another is the explosives safety authority, the third is the explosives safety planner. The definition of each of these specialties is given below.

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## **The Explosives Safety Engineer/Scientist**

Explosives Safety engineers and scientists are usually trained at the university level in general engineering principles, then obtain specialized expertise in explosives safety once they have earned their degrees. Their extensive knowledge and expertise is often required to accurately evaluate an explosives safety situation. Their technical training is often essential to know how to break down a problem or a question into components that can be properly dealt with in a logical manner to provide a technically sound solution. They provide the knowledge base and test data necessary to support the development and maintenance of the existing rules and regulations governing explosives safety.

## **The Explosives Safety Authority**

The explosives safety authority is knowledgeable in and responsible for development application, maintenance, and enforcement of criteria and regulations as they apply to the siting of and operations conducted in explosives-related facilities. They know why the regulations exist, where the data supporting the regulations came from and what the weaknesses are in the criteria. They contribute to and improve the criteria and regulations and they approve/disapprove siting requests and operational procedures. They monitor the safety of explosives handling facilities and their operations.

## **The Explosives Safety Planner**

The installation planner deals with explosives safety criteria whenever it occurs at the installation. This may occur once every few years. It may occur more or less often. When the explosives safety issues are in front of the planner, he/she can usually gain a good understanding of the requirements and problems he/she faces. Since it will often be later than sooner that another similar planning event occurs, the planner will not usually be able to maintain a high level of proficiency in explosives safety considerations.

The explosives safety planner generally does not have the technical background and insights into why certain rules exist. The explosives safety planner applies the siting rules and regulations to planning, design, construction and maintenance of explosives-related facilities. These people make sure that existing and new facilities are built and maintained in a safe manner. They advise decision makers with regards to planning matters. They prepare and submit siting requests. Their knowledge of explosives safety issues can vary over a wide range extending from extensive experience to minimal knowledge with very little experience.

## **PURPOSE & SCOPE OF THE AUTOMATION PROCESS**

Many explosives safety experts have competence in more than one of the areas described above. The specialty areas have different automation requirements. Explosives safety authorities and planners need to be able to determine how specific facilities stand up to the governing laws and criteria. They need to be able to tell if unsafe conditions may exist and if further investigation or evaluations should be made. They need to know what kind of expertise should be brought in to resolve problems found to exist in the field, or answer questions about whether proposed uses

for existing facilities are valid.

The evaluation of the effects of an internal explosion on a structure and its associated debris throw is an involved procedure that requires a knowledgeable user. The analyst often must use multiple computer analysis tools and keep the data organized and consistent as the analysis progresses from one computer program to another in the evaluation. Evaluations of this type are traditionally performed by engineers trained in the specialized field of the effects of explosions on structures. The explosives safety planner in the field currently has no automated capacity whatsoever to even perform an approximate safety evaluation of a situation he/she is faced with in actual practice. Complex regulations and increased utilization of existing facilities only compound the problems of explosives safety planning. The DDESB has noticed that explosives safety planning is currently in decline at some military installations due to reductions in personnel, complex regulations and the inexperience of planning personnel.

Explosives safety authorities and planners need automated tools to be able to determine how specific facilities stand up to the governing explosives safety laws and criteria. They need automated tools that will assist them to determine if unsafe conditions may exist and if further investigation or evaluations should be made.

Explosives safety engineers/scientists need refined tools that will assist them in more detailed, specialized analysis. They are the only ones that can determine if a structure will fail under a predicted blast loading. If a structure does break up and fail, they can predict the extent of damage to both the structure and nearby facilities. They can assess the risk to nearby personnel, how far debris will fly, etc...

## **PLANNING APPLICATION**

When an installation has to modify or site an explosives-related facility they must go through the siting process. They must look at the facility first as a Potential Explosive Site (PES). They must look at all surrounding facilities as Exposed Sites (ES). Appropriate Explosives Safety Quantity Distance (ESQD) arcs are then computed according to existing rules and regulations then drawn on a map to establish the safety of the proposal. If all is ok, then a reverse calculation is performed. The proposed facility is then looked at as an ES, while all nearby facilities are looked at as potential PES's. The investigation must include all possible PES's. If there are no ESQD conflicts, a siting approval request is then prepared and submitted through the approval process. There are times when a particular proposal is highly desirable for economic reasons, such as in the case when the operation at an expensive existing facility is proposed for expanded use. If ESQD conflicts are found, a refined engineering analysis may show that the facility actually does conform to the intent of the regulations, or that economical mitigating methods can be used to provide a level of safety that is as good as or better than the regulations. In these cases, Explosives Safety Authorities will accept the engineering analysis over the published regulations and approve the facility. The Explosives Safety Planner and the Explosives Safety Authority may not know if the cost of an engineering analysis will be worthwhile. They need automated tools that allow them to perform approximate analyses to determine if a more costly, refined analysis will be of benefit to them.

Automated tools are being developed to assist the planner with both of the above requirements. These tools include an automated version of the DoD, Army, Navy and Air Force siting criteria, and a limited application of the DDESB Technical Report 13.

Automated installation planning is at various levels of maturity at activities throughout the DoD. Some activities have a full installation data repository in electronic format. They use automated tools to perform planning and life-cycle management functions. Other activities have uncoordinated collections of data. This data is stored in hard copy format in filing cabinets. Installation planning is largely a manual effort. We expect that these extremes in automated capability will continue to exist for another 20 years.

An automated tool called the Quantity-Distance Engine (Q-D Engine) is currently under development under the direction of the DDESB that is designed to evaluate and produce siting approval requests. This tool will cover the needs of all facilities in the above spectrum.

The Q-D Engine is a non-graphic computer program that will evaluate PES-ES relationships and determine the required quantity distance in accordance with the appropriate explosives safety siting regulations. There will eventually be four versions of this engine: one for DoD, Army, Navy and Air Force. The DoD version of the Q-D Engine is currently under development and will be available in early 1999. The other versions of the Q-D Engine will be available in June of 1999. The Q-D Engine is designed to function as a subroutine that is called by other computer programs to perform siting analysis. It will evaluate one or thousands of PES-ES combinations. The fully automated installation will have a sophisticated Explosives Safety Siting program that will automatically extract PES-ES combinations, along with their associated data, launch the Q-D Engine, then format the resulting calculations into a formal siting request format. Installations that are not automated will launch a Q-D Calculator program that will prompt the user for the necessary input data, perform the Q-D calculation and print out the answer. The siting approval request can then be prepared manually for submittal. In either case, the most difficult, time consuming and error prone process of actually performing the siting calculations will now be fully automated. The reader is referred to the paper entitled "Start the Q-D Engine" given at the poster board session of this seminar for more information on the Q-D Engine.

Another tool to assist the planner in performing approximate debris throw analysis is envisioned for development in the near future. The application will be based on DDESB Technical Paper TP-13. This paper defines a procedure to determine a safe debris throw distance for explosives related facilities of various types of construction. It is currently limited to a maximum Net Explosive Weight (NEW) of 250 lbs. The methodology is currently being expanded to allow analysis of NEW's of up to 8,000 lbs. We are also looking at ways to justify higher NEW quantities if a disclaimer is attached that indicates that conservative assumptions have been made to the methodology that indicates that the safe debris strike range will be no greater than a certain distance (conservatively over-predicted). This will assist the planner to perform a preliminary assessment of a situation that exists at an activity. If a conservative analysis indicates that the safe debris distance can be less than the published regulations, that justification can be submitted for approval. If the predicted safe debris strike range answer is borderline, then the planner can decide whether to investigate a more refined analysis and/or examine mitigation technology to resolve the siting problem.

## **ENGINEERING APPLICATION**

There are numerous explosives related computer programs that have been developed to assist in predicting the effects of explosions on structures. Most of these programs have been

sponsored by or developed directly by the government. Nearly all of them assume that the user has significant technical knowledge of the subject, and they all require engineering judgement to some extent in their use. They all have been developed for use in a stand-alone single program execution format. Recently some of these stand-alone programs have been pulled together into combined-use applications such as DISPRE2, ERASDAC and the tri-service publication "Design and Analysis of Hardened Structures for Conventional Weapons Effects (DAHS-CWE) (Army TM5-855-2). Each of these software packages is a valuable tool for the analyst.

NFESC is in the process of developing another combined-use program to facilitate the automation of explosion-effects modeling of accidental explosions. The application will ultimately provide the capability to predict the blast and fragment loads generated from an explosion, evaluate the capacity of a structure to resist the effects of an explosion, and predict the damage and debris throw generated by an explosion. The computational options of this program are shown in Figure 1.

The basic structural model for the initial version of this program is shown in Figure 2. The structure (or room) is assumed to be rectangular in shape. Basic dimensions of the structure are required along with the location of the Maximum Credible Event (MCE) Figures 3-5.

The remainder of the data input is dependent on the type of analysis that is to be performed. Blast loads will be computed based on the user-defined location of the blast with respect to the model. If the MCE is positioned inside of the model, blast loads will be predicted according to established procedures for an internal explosion. If the MCE is located outside of the model, an external loads computational procedure will automatically be invoked. The program initially will use the computer programs SHOCK, FRANG and OVERPRESS to model the internal and external blast loads. OVERPRESS is a computer program developed at NFESC that is based on the tri-service manual "Structures to Resist the Effects of Accidental Explosions", Army TM 5-1300. Pressure buildup inside of a structure will be modeled using an automated procedure also based on procedures outlined in TM 5-1300. Frangible panels must be designated as such in the initial versions of this program. Later versions of the program will allow the user to model connections in the model and the frangibility of these elements will be determined automatically.

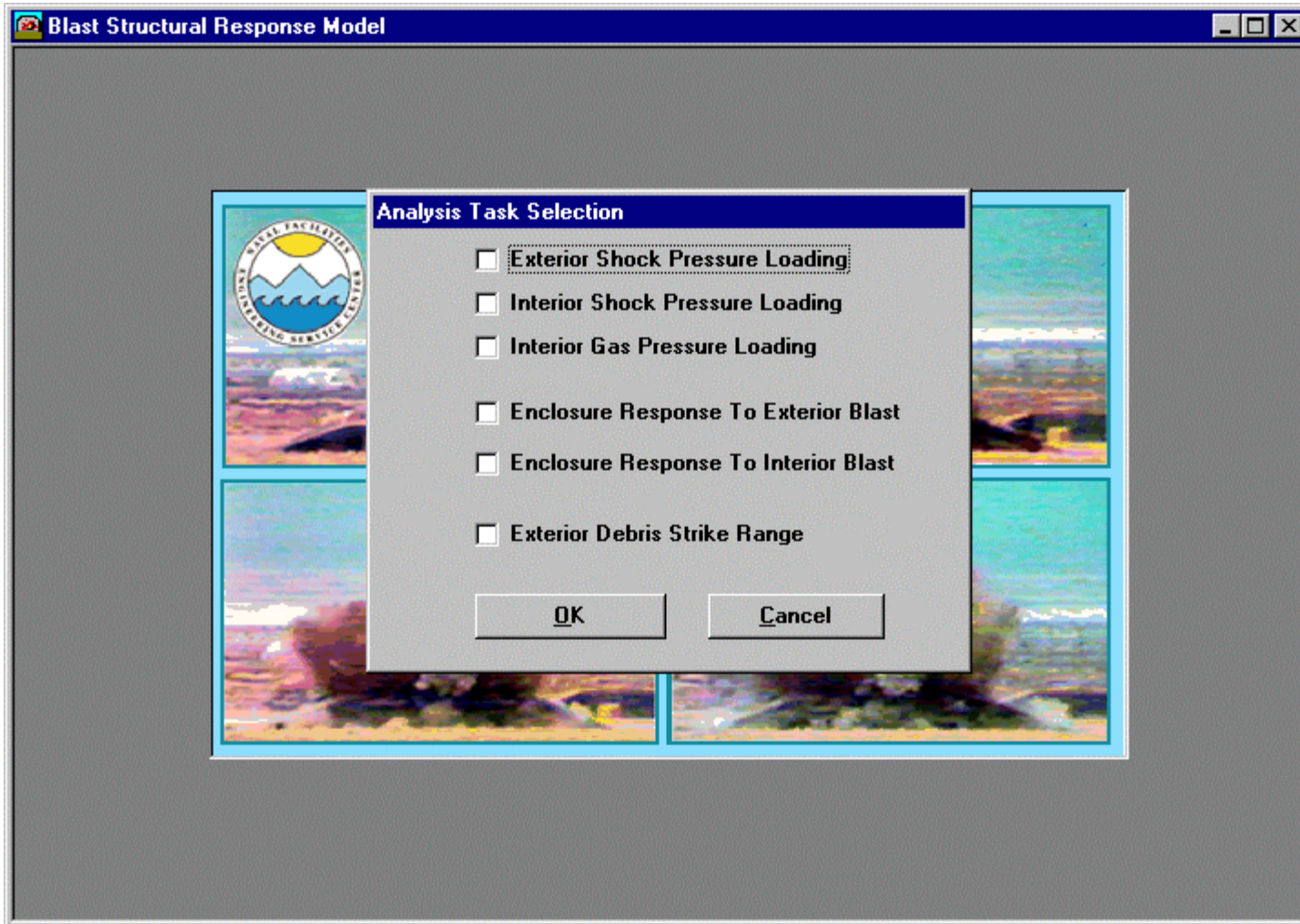
If the user selects a dynamic response analysis, input of material properties will be required to allow the computation of dynamic response properties and dynamic response. Dynamic response analysis will only be allowed for structural materials such as glazing, reinforced concrete, reinforced masonry and steel. The program will assume that other types of materials are not structural in nature and will fail when any significant overpressure load is applied. Glazing properties and response will be computed using the computer program SAFEVIEW. Reinforced concrete and masonry properties will be computed using the computer program CONPROP, which is a revised, updated version of the computer program BARCS. Steel properties will be computed using the program STEELPROP, which follows procedures outlined in TM 5-1300. The maximum deflection of structural elements is predicted using the computer program SOLVER, which assumes a single degree of freedom response model. Maximum deflection must be associated with absolute limits to determine if a structural element has failed. The definition of structural failure can be determined automatically via assumed allowable support rotations, or can be defined by the user.

Debris / Fragment analysis will predict the strike range of debris generated by an explosions. It is integrated with the structural analysis which first determines if there is significant

breakup or failure. If there is, it will pass on to the debris analysis the essential information required to perform a debris throw analysis including launch velocity, mass, launch angle, drag coefficient, etc... This computation will also provide a capability to evaluate mitigating factors such as extreme terrain. The computational procedures will use elements of the computer program DISPRE2, which includes BLASTX, MUDEMIMP and TRAJ and are modeled after DDESB TP-13 procedures.

## **SUMMARY**

A combined effort by the Department of Defense Explosives Safety Board (DDESB) and the Naval Facilities Engineering Service Center (NFESC) to integrate numerous explosion modeling procedures is underway. A software package is currently under development that will enable the automation of DoD, Army, Navy and Air Force explosives safety siting criteria. This software is referred to as the Q-D Engine. Another software platform is being developed that will allow the integrated modeling of a wide range of explosion-related phenomenon. Computational procedures that are currently integrated include the modeling of confined explosions, external explosions and prediction of debris throw. In FY99 work will begin that will add the capability to perform dynamic structural analysis to determine if the structure can withstand the effects of an accidental explosion. The capability of predicting debris throw will be significantly enhanced with the inclusion of the complete DISPRE2 methodology developed for DDESB and Klotz Club by SouthWest Research Institute. The ability to account for the effects of terrain and structural obstacles on debris strike distances will also be included in the package.





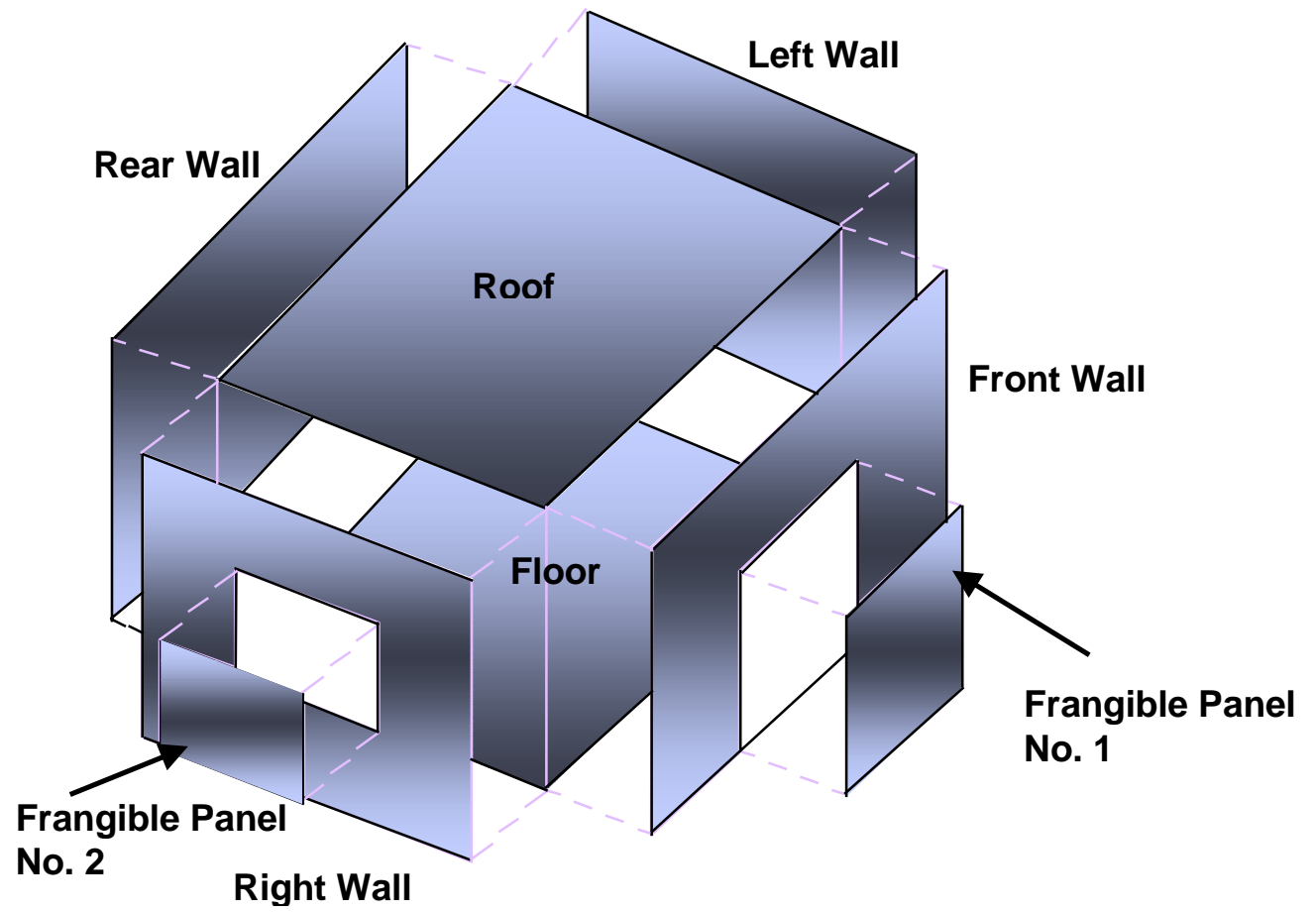


Figure 2. Data Model for structure.

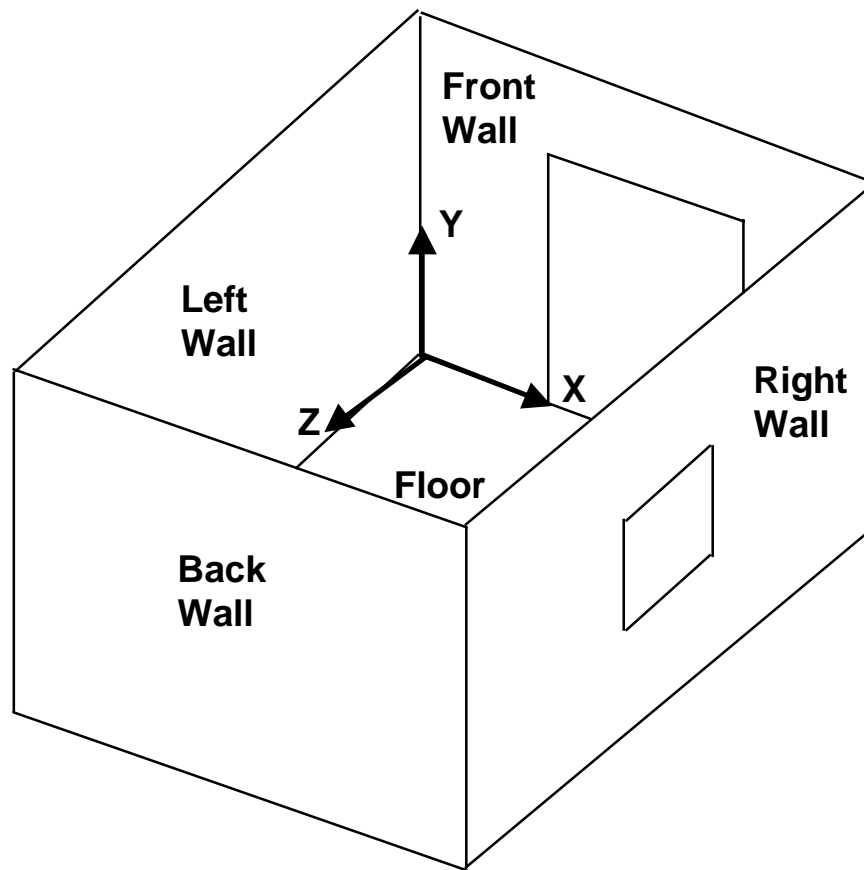


Figure 3. Coordinate system of model.

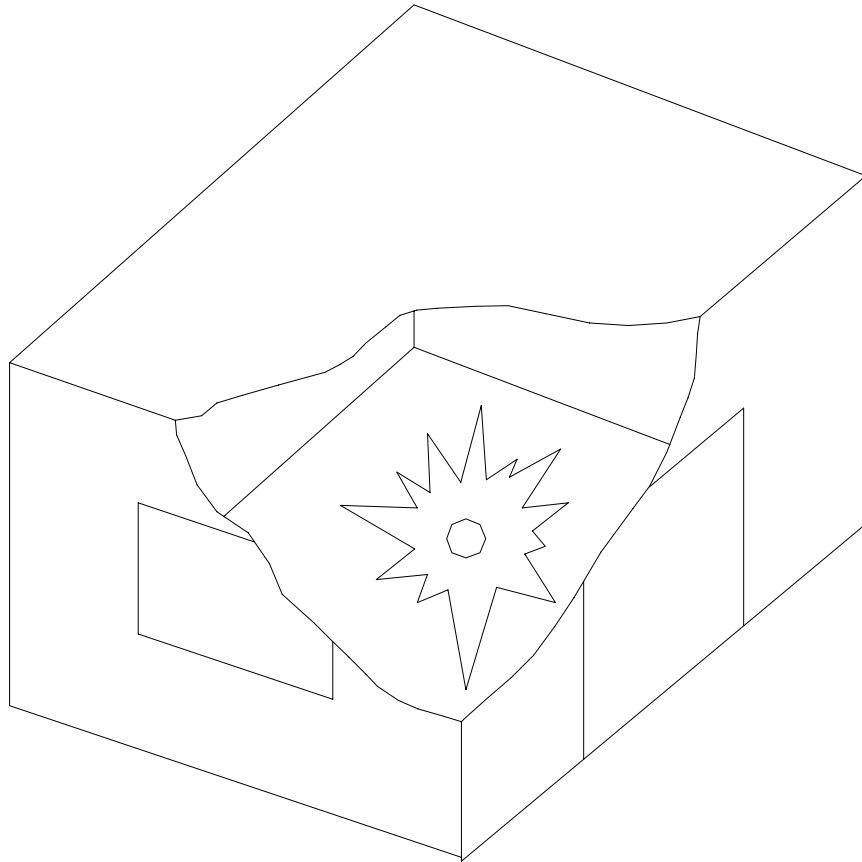


Figure 4. Location of Maximum Credible Event.

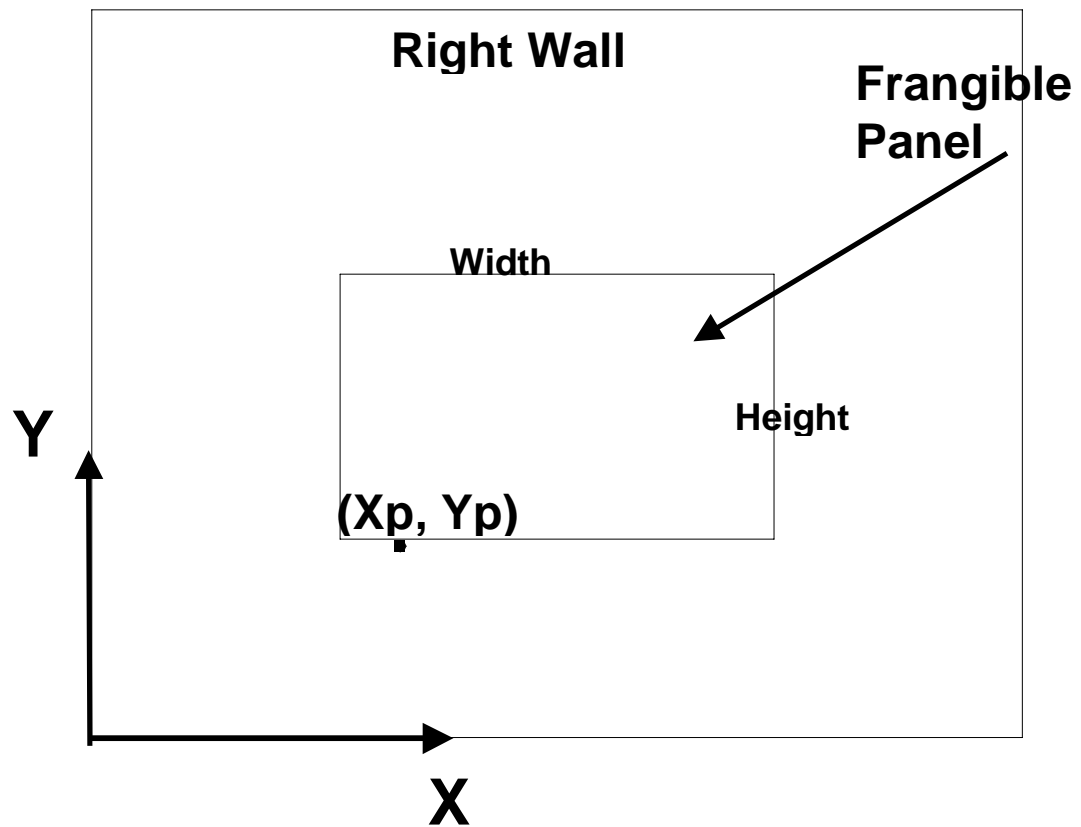


Figure 5. Local coordinate system of structural components.